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A METHOD MAKING POSSIBLE THE UTILIZATION OF AN ILLINOIS JOINT CLAY

BY

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AN ATTEMPT TO DETERMINE THE AMOUNT OF HEAT UTILIZED FROM A DOWN-DRAFT KILN BY THE WASTE HEAT DRYING SYSTEM

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AN ATTEMPT TO CALCULATE THE AMOUNT OF HEAT UTILIZED FROM A DOWN-DRAFT KILN BY THE WASTE HEAT DRYING SYSTEM.*

BY

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In a test made some time ago the heat distribution of a down-draft kiln employed for burning hard building brick was calculated, based upon careful measurements of the kiln and exit temperatures, the composition of the waste gases, the fuel and the ashes, together with the weight of the coal and of the ware. The result was summarized as follows:

Heat lost by the fuel gases	27.33%
Theoretical Heat required to burn the bricks	19.55%
Heat lost by unburnt carbon in ash	3.51%
Heat taken up by kiln and lost by radiation	49.61%

At the close of the burn a 30-inch goose-neck was inserted into the door of the kiln which connected with an underground flue leading to the dryer. The air was thus drawn from the kiln by means of the large fan located at the dryer. A draft gauge was then connected with the goose-neck for determining the "head" caused by the pull of the fan. This was found to be quite uniform and equal to 14 divisions of the Richardson-Lovejoy petroleum gauge which corresponds to about 1/4 inch of water by actual measurement. A thermo couple was likewise inserted into the goose-neck which was replaced later by thermometers.

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In this manner the temperature of the air leaving the kiln was carefully measured for 108 hours.

In attempting to calculate the amount of heat exhausted from the kiln by means of the fan we must know first the velocity of the air through the pipe. This it was only possible to approximate, since the draft gauge was not calibrated against an anemometer. The final value of the velocity accepted is lower than the actual velocity, since no attempt was made to use the Pitot tube correction factor, which is greater than unity. The theoretical velocity calculated from the head shown by the gauge, giving a lower value was hence used, neglecting the decrease in the viscosity of the hot air and other factors due to cooling between the kiln and the fan. This, it is believed, did not introduce any significant error, since evidently the velocity was fairly uniform throughout the test. The velocity is thus calculated from the formula.

$$v = \sqrt{2\ g.\ h \frac{d_1}{d_2}}$$

v = velocity in meters per second.
g = gravity constant = 9.8 m.
h = head of water, expressed in meters = 0.00 m.
d_1 = density of air at 0° C.
d_2 = density of water at 0° C.

substituting we have

$$v = \sqrt{19.6\ .\ 0.006\ .\ 772} = 9.46 \text{ m.}$$

The velocity of the air was taken to be 9.5 m. per second.

The time was divided into nine periods of 12 hours each and the mean exit temperature calculated for every period. These were found to be as follows:

0 — 12	hours	885° C.
12 — 24	hours	715°
24 — 36	hours	640°
36 — 48	"	540°
48 — 60	"	435°
60 — 72	"	355°
72 — 84	"	265°
84 — 96	"	185°
96 — 108	"	135°

With a pipe diameter of 30 inches and using the velocity above calculated we have a discharge of 4.18 cu. m. per second or of 180,576 cu. m. during 12 hours. Owing to the fact that the test was carried on during the dryest and hottest part of the summer, with an average temperature of about 20°, the humidity approximated at 50%. This figure is purely a guess, since the hygrometer was found to have been broken during transit. However, the introduction of the atmospheric moisture factor is not an important one, numerically. Assuming a vapor tension of 8.7 mm, the volume of steam introduced for the volume of air given above would be 2094 cu. m. The barometric pressure was taken to be 750 mm.

There remains now to calculate the weights of air and steam taken through the pipe for each period as well as the heat removed. This is illustrated for the first period as follows:

$$\text{Air....}180576\frac{273}{273+885} . 1.275 . 865 . 0.237 = 11,127,000 \text{ kg. Cals.}$$

$$\text{Steam..}2094\frac{273}{273+885} . 0.797 . 865 . 0.48 = 163,360 \text{ kg. Cals.}$$

Total heat removed by air and steam............11,290,360 kg. Cals.

In this calculation 0.237 and 0.48 are the specific heats of air and steam respectively. Tabulating the results we obtain:

Period	Total number of kg. Calories
1	11,290,360
2	10,632,820
3	10,264,510
4	9,667,880
5	8,858,130
6	8,063,050
7	6,883,290
8	5,444,750
9	4,260,190
Total	75,364,980 kg. Cals.

The coal used during the burn had a calorific value of 6200. Hence the weight of coal equivalent to the amount of heat drawn from the kiln would be

$$\frac{74\ \ 462\ \ 308}{6200} = 12155 \text{ kg. or}$$

26,741 pounds. During the entire burn 95,045 pounds of coal were used. The heat exhausted from the kiln during cooling then equals 28.1% of the total heat introduced, so that the heat distribution could be rearranged as follows:

Heat lost by flue gases	27.33%
Theoretical heat required to burn the ware	19.55%
Heat lost by unburnt carbon in ash	3.51%
Heat stored by kiln and ware and recovered for drying purposes	28.10%
Heat lost by radiation and left in kiln and ware unused	21.51%
	100.00%

The recovered heat thus amounts to the equivalent of practically 400 pounds of coal per thousand bricks, or speaking more correctly, about 130 pounds of coal per ton of burnt clay, which is more than the heat theoretically required to burn the bricks. It is evident that not all of this heat is used in drying bricks, some of it is lost on the way to the dryer and in the latter itself. That a considerable amount of the heat is derived from the hot kiln walls is apparent from the comparison of the figures in the final distribution. Owing to the fact that this test was carried on in summer, the results show the most favorable conditions under which this particular kiln operates. In winter the heat actually available for drying would be considerably less, owing to the increased loss by radiation during cooling.

A METHOD MAKING POSSIBLE THE UTILIZATION OF AN ILLINOIS JOINT CLAY.*

BY

A. V. Bleininger and F. E. Layman.

A large part of Northern and Central Illinois is covered by the so-called joint clays which are of glacial origin and vary in depth from one to five feet. These clays are weathered to different depths and in this condition they form the basis of a considerable brick industry. They are red-burning surface clays, extremely fine in grain, but as is characteristic of glacial deposits, admixed with mineral detritus of all kinds. In a number of localities, however, they are quite uniform in composition for considerable areas and free from excessive amounts of rock debris, gravel, etc.

In the weathered condition they usually work up quite well into bricks and tiles though they are sometimes liable to check in burning. Some distance below the surface, however, they are apt to show a peculiar behavior in drying, giving rise to characteristic splitting and cracking.

When made into bricks they split through vertically into more or less regular cubes, the same thing being observed when a bank is stripped and the surface is drying out. The loss arising from this peculiarity in attempting to make clay products out of this material is quite considerable, since the checking occurs in the drying as well as in the burning, the latter being due probably to incipient cracks.

A typical deposit of this character is found on the land of Mr. J. W. Stipes, close to the city of Urbana, Ill. This clay is extremely fine grained, red burning, very sticky and plastic but not high in bonding power. Within

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a foot of the surface it has been changed by weathering so that it does not show the peculiarity mentioned above to a striking degree but at a somewhat greater depth its true joint structure appears. There are no differences in color noticeable between the weathered and the unweathered portion, both are of about the same yellow. The clay is comparatively free from mineral debris and stands up remarkably well in the kiln. Though at present used for the manufacture of soft-mud bricks and burnt in up-draft kilns, this process does not do the clay justice and does not bring out its best colors, as a down-draft kiln would do. It vitrifies between cones 3 and 4. When burnt at a lower temperature it produces a fine red color.

It has been realized from experience that both weathering and thorough air drying help considerably in overcoming the difficulties encountered in the use of this clay. Hence, by allowing it to freeze through the winter it would become quite workable in the spring. The difficulty is, however, in being sure that all of the clay has been sufficiently weathered, and though the drying loss may be reduced, some loss in burning may still be found to occur, the same thing applying to the air drying.

Considering the benefit derived from air drying, it was proposed to carry this process further and to dry the clay at higher temperatures. For this purpose a sample was taken from that part of the bank, used by the Sheldon Brick Company, that had given the most trouble.

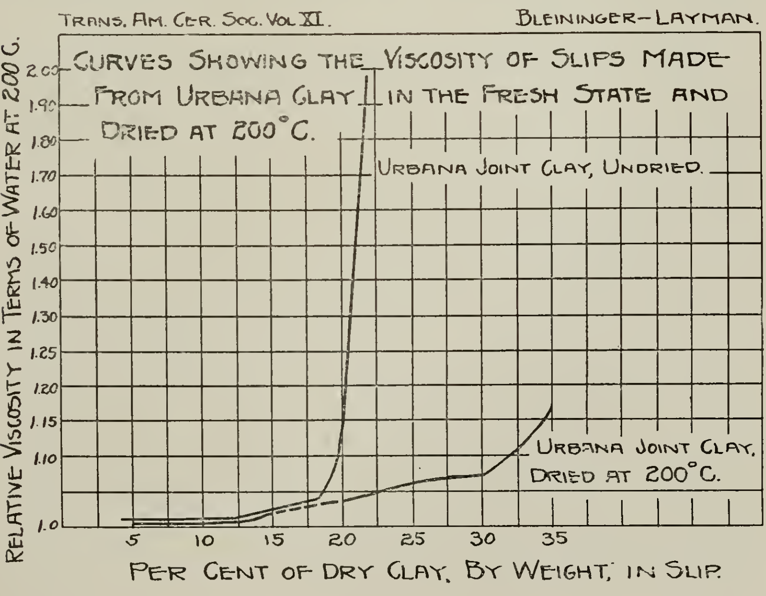
In the preliminary work, small samples of this clay were dried in a laboratory air bath at 100, 200 and 300°C. These were then pulverized, passed through an eight mesh screen, tempered, wedged and pressed into bars, $10'' \times \frac{1}{2}''$ $\times \frac{1}{2}''$ in a brass mould. A portion of the undried clay was also wedged and pressed in the same mould. After drying in the air at ordinary temperature the linear shrinkages were determined. It was found that the bar made from the undried clay warped very badly as well as the bar made from the clay dried at 100°, but that the bars moulded from the clay dried at 200° and 300° showed very little warping.

The linear shrinkages were as follows:

Undried Clay	10.3	Per cent.
Clay dried at 100°	9.7	" "
Clay dried at 200°	7.3	" "
Clay dried at 300°	7.1	" "

In tempering the dried clay it was observed that the sample dried at 100° still possessed the sticky nature of the undried clay, while the charge dried at 200° had lost to a very large extent this characteristic property. At the same time a certain granular appearance was noticed as well as a slight change in color from yellow to reddish. The sample dried at 300° worked practically the same as the one heated to 200°. Hence, it was obvious that whatever changes had taken place in the structure of the clay occurred at about 200° C, and this was the temperature chosen in the work that followed.

In order to bring out the changes caused by this drying treatment, still further experiments were made. A sample of the undried clay was taken and divided into two parts. One-half was dried at 200° in a laboratory oven, the other half was left as it was. Both of these batches were placed in porcelain jar mills of one gallon size, together



with sufficient distilled water to make a fairly thick slip, and ground for one hour. The grinding action of these small mills is very slight so that the fineness of grain was affected but little. Each of the two slips was passed through an 80 mesh sieve.

The viscosity of each of the slips was then determined by means of a Coulomb viscosimeter which had been constructed in the Department of Ceramics, University of Illinois, for the purpose of studying clay slips, as described in Vol. X, Trans. Am. Ceramic Society.

The amount of clay held in suspension in the slips was determined by evaporating the slips to dryness and weighing in small metal pans. In order to obtain the viscosities of lower concentrations, the slips were diluted with water, thoroughly stirred up and tested as before.

In the accompanying curves we observe clearly what great changes have been brought about by the drying treatment. It is evident that this change involves the structure of the colloidal portion of the clay, since naturally neither the size of grain was altered nor anything added to or subtracted from the clay in drying. Just how long a time would be required to bring back the clay to its original state of viscosity, if this is possible at all, would be an interesting question.

We observe from the curves that for instance in the case of the fresh clay a viscosity of 1.18 is reached with 20% of clay, while for the same viscosity 35% of the dried clay is required. The latter therefore shows a marked decrease in the viscosity characteristic of plastic clays.

In order to bring out the differences between the undried and the dried clay still further, another series of tests was made by taking these clays alone and in several proportions and making them up into round discs, 3¼ in. in diameter and 7/8 in. thick. For this purpose the fresh clay was thoroughly wedged, while the dry clay was pulverized and passed through a 10 mesh screen, made up with water and tempered. The discs were made by batting the clay into a slab between two guides and passing a roller over the latter so as to obtain uniform thickness. The slabs were then cut into discs by means of a tin biscuit cutter and when sufficiently stiff they were repressed on a hand screw press provided with a corresponding round die. Ten trials of each series were placed in a Seger voluminometer and the volume determined by displacement in kerosene after having been immersed in petroleum for 24 hours. The same process was repeated after the discs were dry. The average of ten determinations was taken as the drying shrinkage. The dry test pieces were all placed in a Caulkins muffle kiln, fired with oil and burnt to cone 4, this temperature having previously been determined as the best maturing point of the clay. Each of the ten trial pieces of the several series which had been measured for drying shrinkage, was, after burning, again placed in the voluminometer and the volume determined. The balance of the trials were placed in water with one face exposed and allowed to stand for 48 hours, this period of time having been established as the point beyond which practically no further absorption took place. They were then divided into classes according to the absorption found.

At the same time discs were made in similar manner from Galesburg shale which, however, were fired at cone 2, the best temperature for this material. The results of this work are collected in the following tables, the shrinkage being expressed by per cent in volume. The percentages of loss are based upon 200 discs made from the undried Urbana clay, 200 of the dried Urbana clay, and 125 discs of A, B, and C.

Kind of Material	Urbana Clay not dried	Urbana Clay dried at 200°	Urbana Clay 25% dried, 75% undried	Urbana Clay 50% dried, 50% undried	Urbana Clay 75% dried, 25% undried	Galesburg shale
MARK	U	UD	A	B	C	G
Amount of tempering water, in % of dry wt.	33.5	29.9	32.0	31.9	31.0	....
Drying Shrinkage in %, by vol.	41.2	29.3	39.1	35.8	34.1	7.5
Burning Shrinkage in %, by vol.	21.1	20.6	21.0	21.0	20.9	16.2
Drying loss in %	32.0	0.5	26.0	15.3	9.7	....
Burning loss in %	15.0	4.0	9.1	11.0	12.9	2.5
Total loss in %	47.0	4.5	35.1	26.3	22.6	2.5

From these results it is apparent that the pre-heating of the clay has greatly decreased the drying shrinkage, the difference being 11.9 per cent in volume or nearly 4 per cent in linear shrinkage, assuming for practical purposes that the linear shrinkage is one-third of that in volume. A curious fact is also the decreased burning shrinkage, so that the total shrinkage is decreased from 62.3% by volume to 49.9%, resulting in a difference of 12.4%. Or, expressed in linear dimensions, the decrease in total shrinkage is from 20.7% to 16.6%. The loss in drying which took place in the open laboratory at ordinary room temperature has been decreased from 32.0 to 0.5%, a gain of 31.5%. The gain in burning loss was 11% and in the total loss 42.5%.

As to the mixtures of preheated and undried clay, we observe that the shrinkage and losses decrease roughly with the increase of preheated clay and thus these results verify the observations on the preheated clay itself.

Since there is a possibility from the practical standpoint of the drying and burning losses that the same results would be obtained by the addition of sand to the clay, a short series was carried through in which 5, 10 and 15% of sand passing the 8-mesh sieve were added to the undried Urbana clay. Of each sand mixture 125 discs were made. The results of this work are collected in the following table in which the data for the undried and the preheated clay are repeated for the sake of comparison:

Kind of Material	Urbana Clay not dried	Urbana Clay dried at 200°	Urbana Clay undried: 95% clay, 5% sand	Urbana Clay undried: 90% clay, 10% sand	Urbana Clay undried: 85% clay, 15% sand
MARK	U	UD	D	E	F
Amount of tempering water, in % of dry wt.	33.5	29.9	32.0	31.5	31.1
Drying Shrinkage in %, by vol.	41.2	29.3	39.1	37.6	35.2
Burning Shrinkage in %, by vol.	21.1	20.6	20.2	19.3	18.6
Drying loss in %	32.0	0.5	6.1	5.2	5.0
Burning loss in %	15.0	4.0	11.3	33.0	42.0
Total loss in %	47.0	4.5	17.4	38.2	47.0

From these results we observe that the drying shrinkage has been decreased somewhat and the drying loss a good deal, roughly by about 25%. The burning shrinkage also has been reduced, but unfortunately the burning loss, though showing an improvement in the 5% sand mixture, increased very rapidly with more sand. As compared with the total loss of the preheated clay, the gain has been but small and at least as far as the sand used was concerned this remedy offers but little hope for practical improvement since the losses are still too great. The advantage of preheating this joint clay is seen from the small loss in drying and burning. An explanation of the ineffectiveness of the sand mixture perhaps is due to the fact that the clay itself is not changed in its physical properties and we have here simply a case of dilution. With larger amounts of sand we also have in burning certain volume changes which appear to be opposed to each other, so that strains are produced which result disastrously.

In order to show whether the Urbana joint clay after having been burnt apparently to a sound body really was free from incipient checking, it was determined to make rattler tests. For this purpose the burnt discs, free from flaws, were first graded according to their water absorption and compared with discs made from Galesburg shale which had burnt to the best degree of maturity.

The rattler test was made in a Scheibell mill, consisting of a chilled iron receptacle, elliptical in cross section, with a long axis 23 in. in length and a short axis of 7½ in., revolving 31 revolutions per minute. The rattler was first standardized with a mixture of iron jackstones in the shape of 1¼ in. cubes weighing on an average 0.9 pound and Iceland pebbles with an average length of 3⅛ in. and a width of 2⅜ in. The average weight was 0.7 pound. In the standardization the Galesburg discs were used, five of them in a charge which weighed about 2.2 pounds. The combination giving the most constant results was used for the comparative tests of the joint clay discs with the Galesburg test pieces. In each case the results were checked. Finally, two charges were used, 2-C, containing 75 pounds of pebbles and 50 pounds of jackstones and 2-D, consisting of 100 pounds of pebbles and 50 pounds of jack-stones. In using charge 2-C the mill was about 3/5 full and with 2-D it was 4/5 full. The time of running was one hour. It was found that 2-C was a more severe charge than 2-D on account of the element of impact introduced by the mill being less full.

The rattler losses are tabulated as follows:

All discs apparently perfect and showing an absorption of 1% and less	2—C		2—D	
	% Loss		% Loss	
Galesburg shale, G	9.8	9.7	5.5	5.5
Urbana clay, preheated, U. D	12.3	12.8	4.0	4.5
Urbana clay, not dried, U	14.7	14.5	5.0	....
25% preheated & 75% undried Urbana clay, A	11.5	....	....	....
50% preheated & 50% undried Urbana clay, B	11.8	....	....	....
75% preheated & 25% undried Urbana clay, C	11.8	....	....	....
95% undried Urbana clay, 5% sand, D	12.5	....	5.9	....
90% undried Urbana clay, 10% sand, E	12.5	....	6.2	....
85% undried Urbana clay, 15% sand, F	14.1	....	7.4	....

These results show plainly that preheating has improved the resistance of the joint clay to abrasion decidedly, not, of course, due to any change affecting the mineral and chemical structure of the clay itself, but to the elimination of drying defects, incipient cracks and strains caused in drying. If it were possible to dry the fresh clay without injury it would possess the same resistance to abrasion exhibited by the preheated material. The Urbana clay is evidently more brittle than the Galesburg shale, but it is harder, due to the fineness of grain of the joint clay. One might venture to say, judging from the above comparison, that the latter could probably be used as a paving material for streets which are not subject to heavy travel, provided, however, that the clay would correspond uniformly to the sample tested in this work, which is somewhat questionable in the case of glacial deposits.

The addition of sand, according to the above results, contributes nothing to the resistance to abrasion, though it shows an improvement over the undried clay by lessening the checking in drying.

CONCLUSIONS.

From the results of this work it is evident that the faults of the joint clay have been overcome by this preliminary drying treatment at 200°C. The sticky nature of the clay has been destroyed, the drying shrinkage reduced greatly and the burning shrinkage partly, while the losses in drying have been practically eliminated and the burning loss lowered most decidedly. If, therefore, this preheating can be carried on economically in properly constructed dryers, either fired directly or making use of the waste heat of kilns, the treatment thus suggested ought to find more extensive practical application.

At the same time there must be remembered that the dry clay can be disintegrated and screened more cheaply than the clay coming wet from the bank, thus enabling the manufacturer to remove the impurities, such as gravel, lime, pebbles and other mineral detritus, which are especially liable to be present in the glacial clays, more cheaply and thoroughly, besides making the operator independent of weather conditions. Also it is thus possible to produce wares of a higher grade from low grade material and in districts where other clays are lacking. It is self-evident that the increased cost of production caused by this treatment may be prohibitory in localities where it is possible to find clays which do not require this kind of preparation. The matter of the preliminary drying of clay is not new, but the changes brought about by it have not been clearly recognized and its importance in certain cases not considered. It ought to be especially applicable for higher grades of ware such as roofing tiles, hollow ware, terra cotta, etc.

In regard to the cost of drying clays by the rotary dryer, which is the most efficient apparatus for this purpose, some data have been obtained from two firms, A and B.

Firm A recommends a rotary dryer, heated by direct firing, 60 in. in diameter and 40 ft. long. This aparatus is encased in brick. The clay is fed automatically and at a constant rate, this being very important. About 35,000 common and from 5,000 to 6,000 fire brick are required in the construction. The total weight of the dryer is about 40 tons. The cost of the dryer, complete, is $3000, to which the freight is to be added. This machine will dry 15 tons of clay per hour. It will require 8—12 horsepower to operate and for a material containing 15% of moisture the fuel consumption would be about 500 pounds of coal per hour, at the rate of 15 tons of clay for the same length of time. Including labor and depreciation the cost of drying is estimated at 10 cents per ton.

The firm B estimates the cost of the dryer to be $3,599 and cost of erection at $630. The power required is 20 horse-power and the fuel consumption 60 pounds of good coal per ton of bank clay. The cost of drying is estimated to be 12 cents per ton of bank clay.

In this connection we must remember also that the size of the brick moulds, etc., must be reduced in order to correspond to the decreased shrinkage of the preheated clay, though this does not mean that a saving is effected.

Further work is necessary to determine to what extent this method may be applied to materials other than the joint clay discussed in these tests.

Practically all the laboratory work of this investigation was done by the junior writer, Mr. F. E. Layman, the senior writer having planned the experiments and assisted in writing up the results. The means for carrying on the tests were furnished by the Ceramic Department of the University of Illinois, through Prof. C. W. Rolfe, the director.